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STORAGE BATTERIES OF TOMORROW

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ABSTRACT:

In recent years many interesting changes have been noted in the field of storage battery and electric cell design. New designs have appeared and the commonly known types of storage batteries and cells have been subject to significant modernization. Characterization of these designs is presented in this article, with greater attention given to storage batteries and the newest, most modern electric cells.

Several examples are included in the article to indicate the direction of efforts on portable sources of electric energy.

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Storage batteries and electric cells belong to those sources of energy for which designers of various devices and vehicles provided with electric power have a special partiality. This is, after all, quite justified because they are, to a large extent, independent and portable sources of energy and the power requirements of electric motors for various electric and electronic devices and complexes frequently call for just such sources. Hence, there are wide possibilities for their use. Even if many users are also interested in electric cells, attention is basically focused on storage batteries, specially on those which provide many cycles of charging and discharging.

In recent years many interesting changes could be noted in the field of storage battery and electric cell design. New designs have appeared and familiar types of storage batteries and cells have been subject to significant modernization. When characterizing these designs in the article below, we will pay somewhat greater attention to storage batteries, mentioning, of course, also the newest and most modern, of present, electric cells.

HOW IS A STORAGE BATTERY CHOSEN?

In the design and, above all, in the selection of a storage battery, its prospective operating conditions are taken into consideration. Just the operating conditions of the storage battery determine the character of a compromise, usually made by the builder of the electric device, who must choose between the amount of peak voltage and the duration of the discharge period, between total capacity of the storage battery and its weight and external dimensions, and finally between the more or less troublesome methods of operating storage batteries available to him. It is not surprising that there are almost as many types of storage batteries as there are possible uses.

The variety of storage batteries means that at the same time there is a great dissimilarity between their virtues and defects. In order to justify that statement it would be proper to take into consideration the following 16 basic characteristics of storage batteries:

1. The amount of energy provided by the storage battery in relation to its unit weight.

2. The amount of energy provided by the storage battery in relation to its unit volume.

3. The total energy capacity of the storage battery when discharging steadily.

4. The total energy capacity of the storage battery when discharging in impulses.

5. Storage battery retaining power of live energy and good storage and preservation conditions.

6. Quality of regulating charge level in the storage battery.

7. Time of use - vitality of the storage battery (number of charge - discharge cycles).

8. Operational characteristics in high temperatures.

9. Operational characteristics in low temperatures.

10. Production, sale and operation costs.

11. Requisite functional operations.

12. Ease of servicing, charging and connecting inside energy receivers.

13. Operational infallibility.

14. Consistency and mechanical reliability of design.

15. Pleasing and esthetic external appearance.

16. Ease and accessibility of purchasing.

A storage battery rated good in each of the 16 above categories would be ideal. However, in actual designs the improvement of one feature usually occurs at the expense of another.

By using the comparisons in the table of numbers refering to the 16 characteristic qualities, one can form a general opinion about storage batteries. In this manner, each of the available storage batteries can be rated good, average or poor in relation to those characteristics of the battery which are most important in a given situation. The enclosed table accurately illustrates an evaluation of some new storage batteries, assuming they will be put to general use, mainly in electric vehicles and portable equipment or in devices using direct current. It must be added that this evaluation of characteristics presented in the table was made by the director of development for the famous American torage attery ompany, Burgess, who is noted as an authority on storage batteries.

NUMERICAL EVALUATION OF STORAGE BATTERY CHARACTERISTICS			
Type of storage battery	Evaluation of Characteristics		
	Good	Average	Poor
Nickel - cadmiam	1,3,4,5,7,9,11, 12,13,14	2,6,8,10,16	15
Lead - acid	2,3,4,7,8,9,10	1,6,11,13,14,16	5,12,15
Nickel - iron	5,6,7,11,12,13,14	1,2,3,8,9,	4,10,15,16
Silver - zinc	1,2,3,4,6,9	5,8,12,13,14	7,10,11,15,16
Silver - cadmiam	2,4,5,6	1,3,7,8,9,10, 12,13,14	11,15,16

From the comparison given in the table above it is clearly seen that the battery rated best is characterized by high quality in several categories but simultaneously is quite mediocre in others. For example, none of the selected storage batteries arouses the admiration of the above mentioned specialist in respect to pleasing external appearance (15). Also, the last of these types of storage batteries, in his opinion, are usually difficult to purchase (16), troublesome to operate and rather expensive. However, in spite of these and similar troubles and difficulties, perhaps in this proverbial sea of types one can fish out good specimens. Storage batteries are already unusually appealing and in the future there are the excellent storage batteries of tomorrow.

When referring to modern types of storage batteries we mainly have in mind those which recently went into production and are for sale and those which are not yet on display, in equipment exhibitions or are found i- enterprise prospectuses. These storage batteries are still in the experimental stage and are used only in testing, but much has already been said and written about them.

Efficiency Is Primary

It is known that high energy efficiency of storage batteries, that is, the capability to produce large amounts of energy per kilogram of storage battery weight, is a very desirable feature in every area of storage battery application and in some cases it is the most essential feature. This applies above all to batteries used to power electrically driven vehicles and other equipment with electric motors as the principle source

of power. An effective new storage battery must be characterized by lightness and small size. so that it is not a fundamental factor in the overall weight balance of a vehicle. At the same time such a storage battery must produce electrical energy in rather great intensities for a period sufficiently long to assure maximum range for the vehicle.

The American firm, Gulton Industries, Inc., is developing such a storage battery, the lithium - nickel - fluoride battery, intended for the experimental electric car "Amitron." On the right (Figure 1), we show the lithium - nickel - fluoride battery in a woman's hands, figuratively demonstrating its unusually small dimensions.

The basic characteristics of this type of storage battery are quite attractive. The principle attraction of the Gulton firm's battery is its energy efficiency which is 220 Wh/kg, proving to be the highest yet achieved in this area and realized on a production scale. In contrast to the 4 Wh/kg efficiency for the silver - cadmium battery, 32 Wh/kg for the nickel-cadmium battery and even 90 Wh/kg for the silver - zinc battery, its value is impressive. It must be noted here that this energy efficiency level has been demonstrated by a prototype of the lithium - nickel - fluoride battery and so one must expect that, during mass production, technological improvements which naturally occur in the industry can lead to a further increase in electrical energy produced per one kilogram of weight of this type of storage battery.

Here are other characteristics of the Gulton lithium - nickel - fluoride battery: weight is about 30 kg, maximum power delivered by the battery is 10 kw (while in motion - 8400 w), (in the enclosed diagram, Figure 2, the point of maximum load is designed to be 120 A at 70 V). Operating temperature range is from -40 to +72°C.

The design, itself, of the $Li/Ni/F_2$ battery is quite simple, as illustrated in Figure 3, a schematic cross section of the battery. In the container made of artificial material, nickel - fluoride plates separated from the lithium by a porous plastic separator are submerged in electrolite consisting of a solution of propylene carbonate and phosphoroflouride potassium. The battery is very pleasing to the eye, has a compact design and does not require special handling during operation. It was noted in available publications that the cost of the lithium - nickel - fluoride battery is only 50% higher than the cost of lead - iron batteries, mainly due to the technology of electrode production and the cost of lithium, which is more expensive than lead.

We have already noted how important in the evaluation of the operation of batteries is knowledge of the conditions of their use: charging and discharging, and also operation in conjunction with auxiliary batteries. For a full evaluation of this type of battery it will be helpful to briefly describe how it operates in the "Amitron" vehicle in conjunction with a nickel - cadmium battery, used there as a battery for starting power, operating when there is great consumption of electrical energy.

When the electric vehicle is running at a steady speed of about 50 km/hr. the engine requires about 50 A, which is completely supplied by the lithium

battery which at the same time can charge a nickel - cadmium auxilary battery. However, when the vehicle accelerates, voltage increases greatly, even up to 450 A, which in no case can be supplied by the lithium battery. Then the electronic system which automatically controls charge and discharge of storage batteries switches to parallel operation with the niclel - cadmium battery. When vehicle acceleration ceases, the nickel - cadmium battery automatically is disconnected from the power circuit and switches to charging.

So, observing the performance of the lithium - nickel - fluoride battery in a practical operation, in this case when it supplies power for the motor of an electric vehicle, we see clearly also certain negative aspects of this "sensational" device. Indisputedly among its basic shortcomings is its low charging power with maximum current, reaching barely 8.5 kw and resulting in the necessity for operation in conjunction with other batteries which frequently have lower energy efficiency but have much greater charging power. It follows that to efficiently use this type of battery, the adoption of infallible electronic devices to automatically control charge and discharge of conjunctive batteries is indispensible. Of course, this increases weight and complicates the design of the entire vehicle power system.

The voltage of a single lithium - nickel - fluoride battery without load is 3.2 V but is much higher than the 1.82 V supplied by silver - zinc batteries and even higher than the 2.2 V output of lead - cadmium batteries.

What else can be said about lithium batteries ? Lithium, as the most electropositive of known alkaline metals, is "real dynamite;" it possesses great energy capacity and, at the same time, as the lightest solid body, is perfectly suited, unlike lead, for construction of lightweight storage batteries. However, lithium reacts with water and decomposes, which makes the use of cheap aqueous electrolytes impossible. In the design of the lithium storage battery described here, this problem is solved by the use of a nonaqueous component additive with oxygen content to oxidize the lithium plate and by the use of a special chemical component for ionizing the electrolite in order to increase its electrical conductivity.

Nickel - cadmium storage batteries are not considered a new development but because they are used so widely, including in space telecommunication satellites and also in electrically powered vehicles, we will cover them briefly anyway. These storage batteries are widely manufactured by many makers of storage batteries and electric cells. They are easily purchased. The energy efficiency of this type of storage battery is quite low, about 35 Wh/kg. They are reliable, practical and provide many cycles of charging and discharging.

The voltage of a single nickel - cadmium storage battery is 1.25 V and, therefore, batteries made of this type of storage battery usually contain 10 single storage batteries in order to obtain the required voltage at the battery terminals.

We must also mention the work being done on sodium - sulphur storage batteries such as are being developed in the English branch of the Ford Company. In the sodium - sulphur storage battery made by this manufacturer, electrodes will be in a liquid state but the electrolite is supposed to be a solid.

In the prototype of this storage battery, which is finally supposed to be ready for testing in December of this year, the anode is melted sodium and the cathode is melted sulphur. The electrode are separated from each other by a ceramic membrane (Al_2O_3) whose capacity to conduct positive sodium ions is comparable to the properties of conventional electrolytes. This type of electrolyte is easy to use by ordinary technological methods. The energy efficiency of the sodium - sulphur storage battery is rated at 300 Wh/kg. A theoretical representation of the design of this type of of storage battery is shown in Figure 4.

Because of the fluid state of the electrodes, the storage battery can function in positive temperatures from 250-300°C and also in lower temperatures, if the proper container is set up with thermal insulation to preserve necessary electrode temperature.

Complete charging of the sodium - sulphur storage battery will require, according to current data on this subject, about 3 days, but partial charging, which makes operation of the storage battery possible, can be done in just 10-15 minutes. This storage battery will undoubtedly be cheap because of the low cost of materials for its construction. However, it does have handicaps: the liquid state of its electrode can threaten to explode and its toxic sulphur components can seep out.

Convenience and New Types of Cells

An interesting development in recent years, the zinc - air cell, is in some measure on the borderline between storage batteries and single use electric cells. Quick and repeated "charging" and further operation of a battery of zinc - air cells is possible by the easy replacement of expended zinc anodes. Here is how the cell design looks.

The zinc - air cell is composed of a porous zinc anode and two "breathing the surrounding air" cathodic plates between which is inserted the anode plate. The cathode material is permeable to air but does not let pass the electrolite which is an aqueous hydroxide of potassium. The induction of the electrolyte to the cell is realized by its impregnation of the anode. The porous plate of the anode, also surrounded by the porous material of the separator, is inserted between the cathode plates to the extent that the cell is discharged. During discharging of the cell the zinc of the anode oxidizes, reacting with the surrounding air (hence the name of the cell which, strictly speaking, should be zinc - oxygen), and changes into zinc oxide.

The zinc - air cell has an energy efficiency of about 150 Wh/kg. Batteries of these cells are mainly used to supply power for military field radio stations but the possibility and feasibility of their use as a source of energy to supply power for motors of electrically driven vehicles is also being examined.

Repeated "charging" of a battery of zinc - air cells is done by replacing the anode plates. Already such designs of containers have been developed in which assembled zinc - air cells would comprise a practical solution to the design of a battery of cells for an electric vehicle. Sets of anode replacements have been placed in batteries of zinc - air cells already in use, most frequently for power supply to portable radio communication units. Thanks to this battery it is possible to make a re-charge in just 10 minutes by inserting a set of new, chemically active anodes in place of expended ones. An entire zinc - air battery of this type, together with a set of anode replacements, weighs about 6 kg. One of the zinc - air cells already in production in England is shown in Figure 5. In the picture the zinc anode is partially inserted. The cell has dimensions of 13 X 13.3 X 9.5 cm and it weight about 1 kg.

In general, air ci .iation in zinc - air batteries is by natural convection but many types of batteries of cells also exist for which forced circulation is used. Small ventilators are located for this purpose in electrical devices using this type of cell for power or in the battery itself.

Zinc - air cells are also built in the form of a single life small battery, used in lighting devices for photography purposes, for powering radio receivers, toys and other types of electrical energy loads. The high electrical efficiency of zinc - air cells means that batteries of these cells can in practice replace up to 10 ordinary small batteries. In single use cells the anode is made of a paste of zinc powder and the electrolyte is gelantinous.

A zinc - air cell puts out 1.4 V. Batteries of these cells can function even in low temperatures down to -40°C, although then their energy efficiency diminishes significantly.

Studies of designers in the field of new electric cell construction are continuing and as a result it is certain that new design developments will appear. For example, a new type of dry cell in the form of a tape whose design is shown in Figure 6 can be mentioned.

In a tape cell, the anode forms one side of the tape and the cathode the other; a dry electrolyte in powder form is deposited by a spray method between the tape of the anode and cathode. The tape is rolled up and electric current is gathered by a special collector as seen in the illustration. In the collector, moreover, is fastened the electrolyte activator. It must be added that the whole device forms an unusually light and simple design. The projected areas for applications of the cells are practically unlimited: from toys to artificial satellites and space craft equipment.

These several examples indicate the direction of efforts on portable sources of electrical energy. In observing the achievements of recent years, it can be presumed that the era of heavy, large and low efficiency lead storage batteries is already passing, that significantly improved storage batteries will come into general use and that it is certain that technology has not spoken its last word.

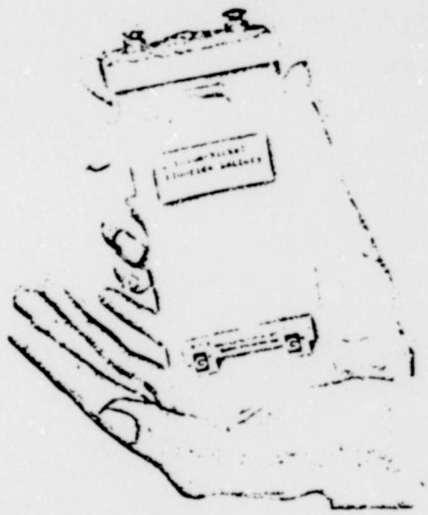
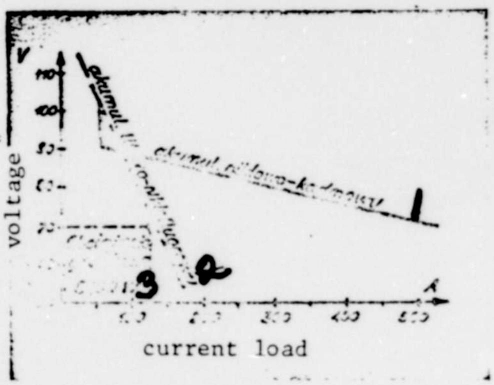


FIGURE 1 - Lithium - Nickel - Fluoride Battery



Key to Fig. 2
1. Nickel-cadmium battery
2. lithium-nickel-fluoride battery
3. critical load 8400 W

FIGURE 2 - Graph of voltage changes of nickel - cadmium and lithium - nickel - fluoride batteries in relation to consumed current (speed of motion) in the "amitron" vehicle.

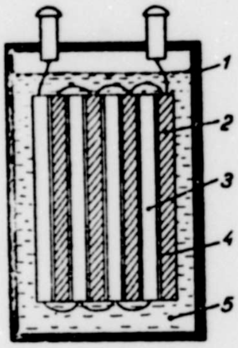
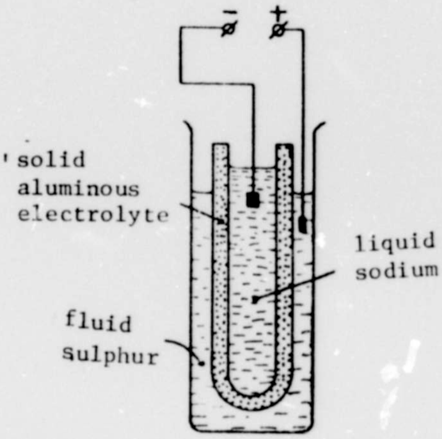


FIGURE 3. Design scheme of the lithium - nickel - fluoride battery:

1. Plastic container
2. Lithium anode
3. Nickel - fluoride cathode plate
4. Porous plastic separator
5. Electrolyte

FIGURE 4. Theoretical

Theoretical scheme of a sodium - sulphur battery



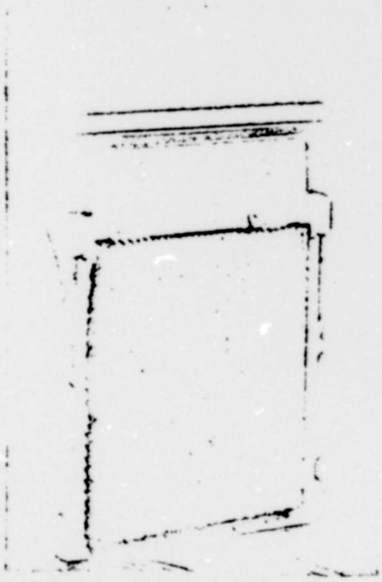


FIGURE 5. Zinc - air cell

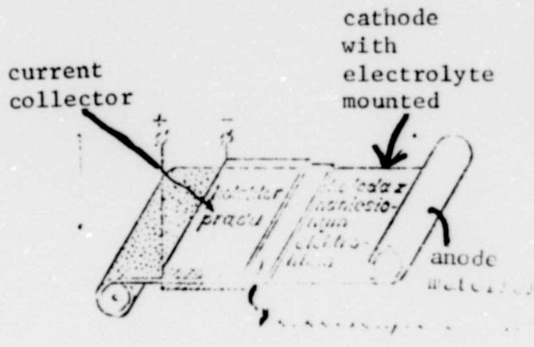


FIGURE 6. Design scheme of tape cell